Signals and Circuits

AERN 35500

Passive Filters and resonance

Chapter 10: 10-8(Basic applications) pp. 473-477

Chapter 12: 12-8(Basic applications) pp. 561-563

Chapter 13: 13-4 (series Resonant Filter) pp. 595-603

Text books:
Floyd, T. L., and Buchla, D. M., *Electroics Fundamentals: Circuits, Devices & Applications*, 8th Edition, Pearson, 2009.

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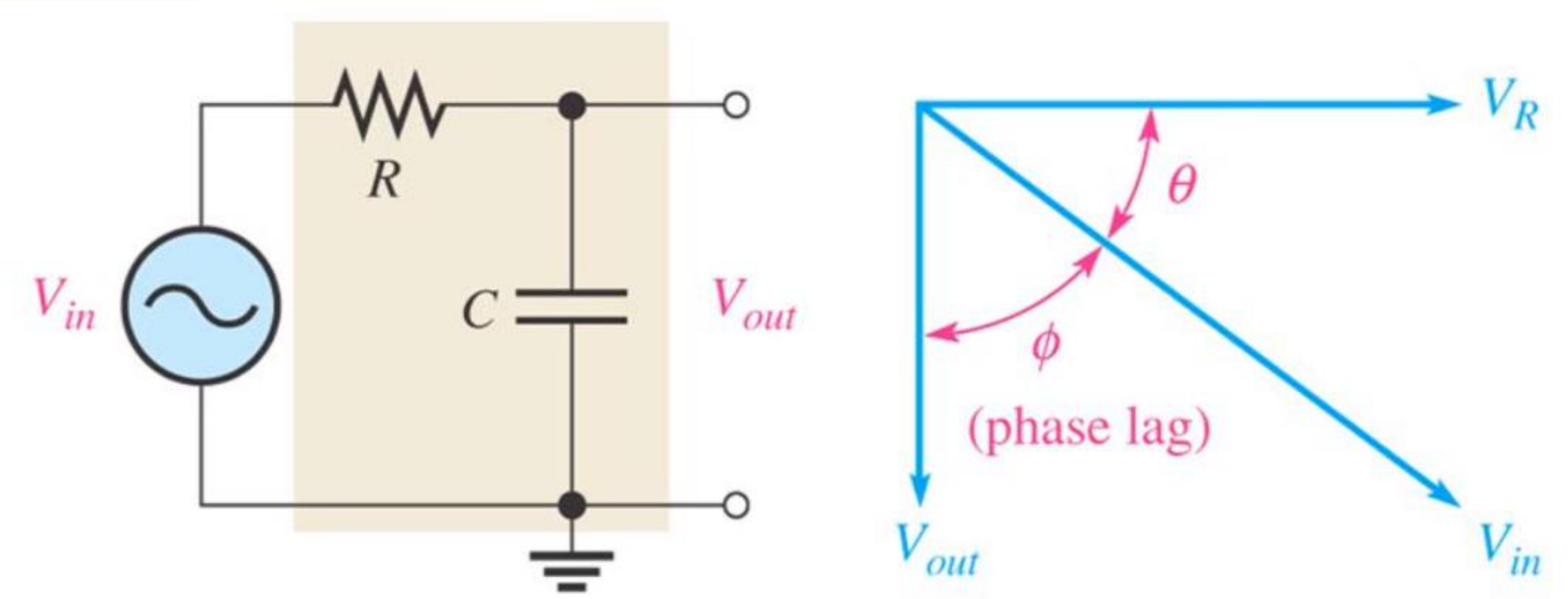
Filter

A circuit that discriminates among frequencies, attenuating (weakening) some while allowing others to pass.

They usually consist of a capacitor and/or an inductor connected in series to a resistor.

The output voltage is taken either from the reactive or the resistive element in the circuit.

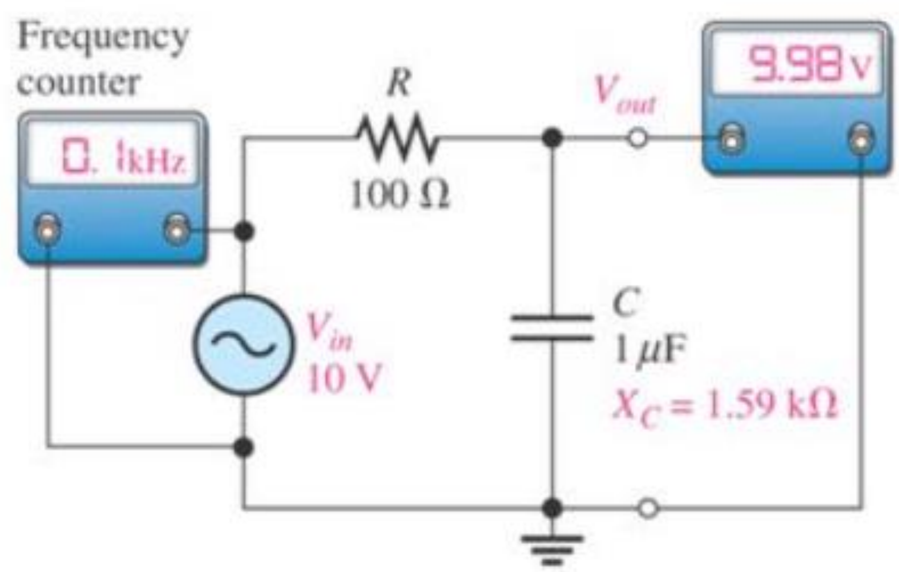
Passive filter



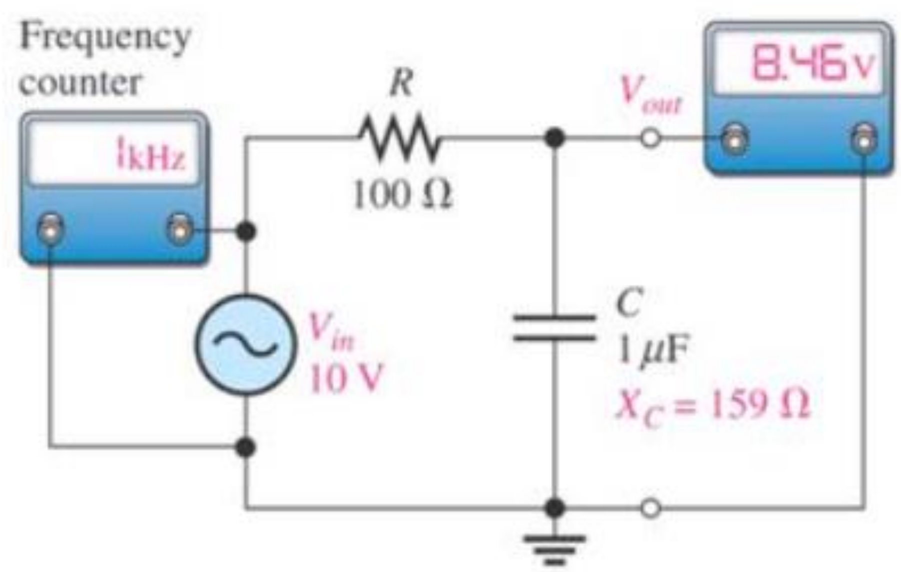
$$V_{out} = \frac{X_C V_{in}}{\sqrt{R^2 + X_C^2}}$$

$$X_C = \frac{1}{2\pi f C}$$

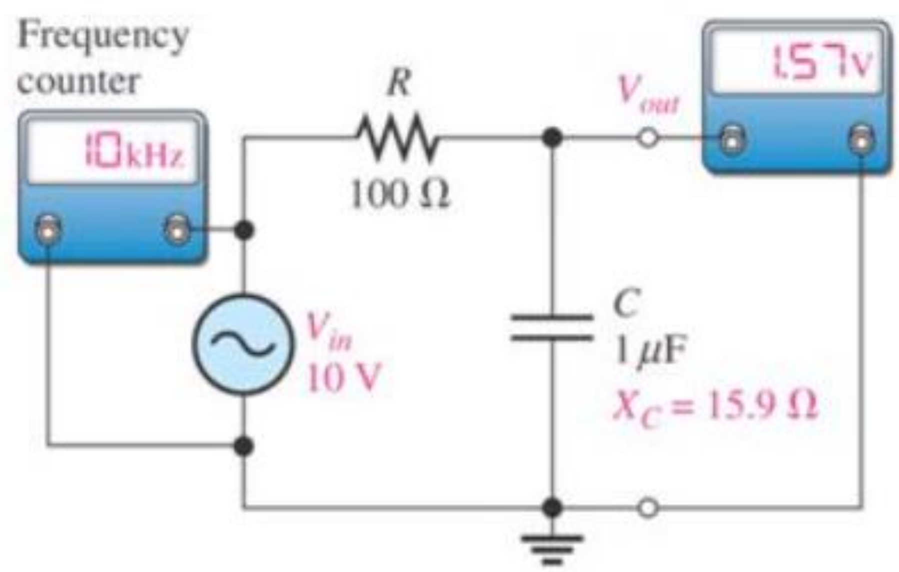
Passive filter

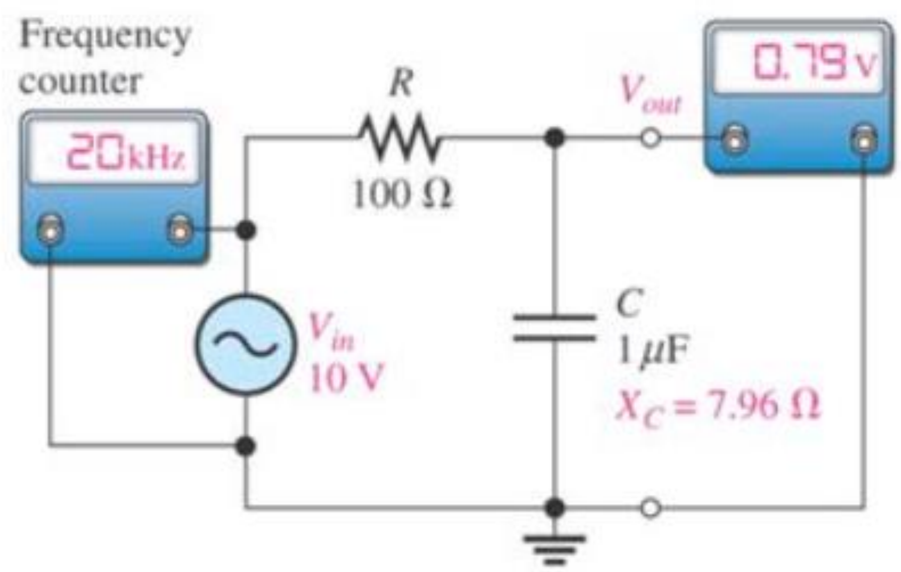


(a) $f = 0.1$ kHz, $X_C = 1.59$ kΩ, $V_{out} = 9.98$ V

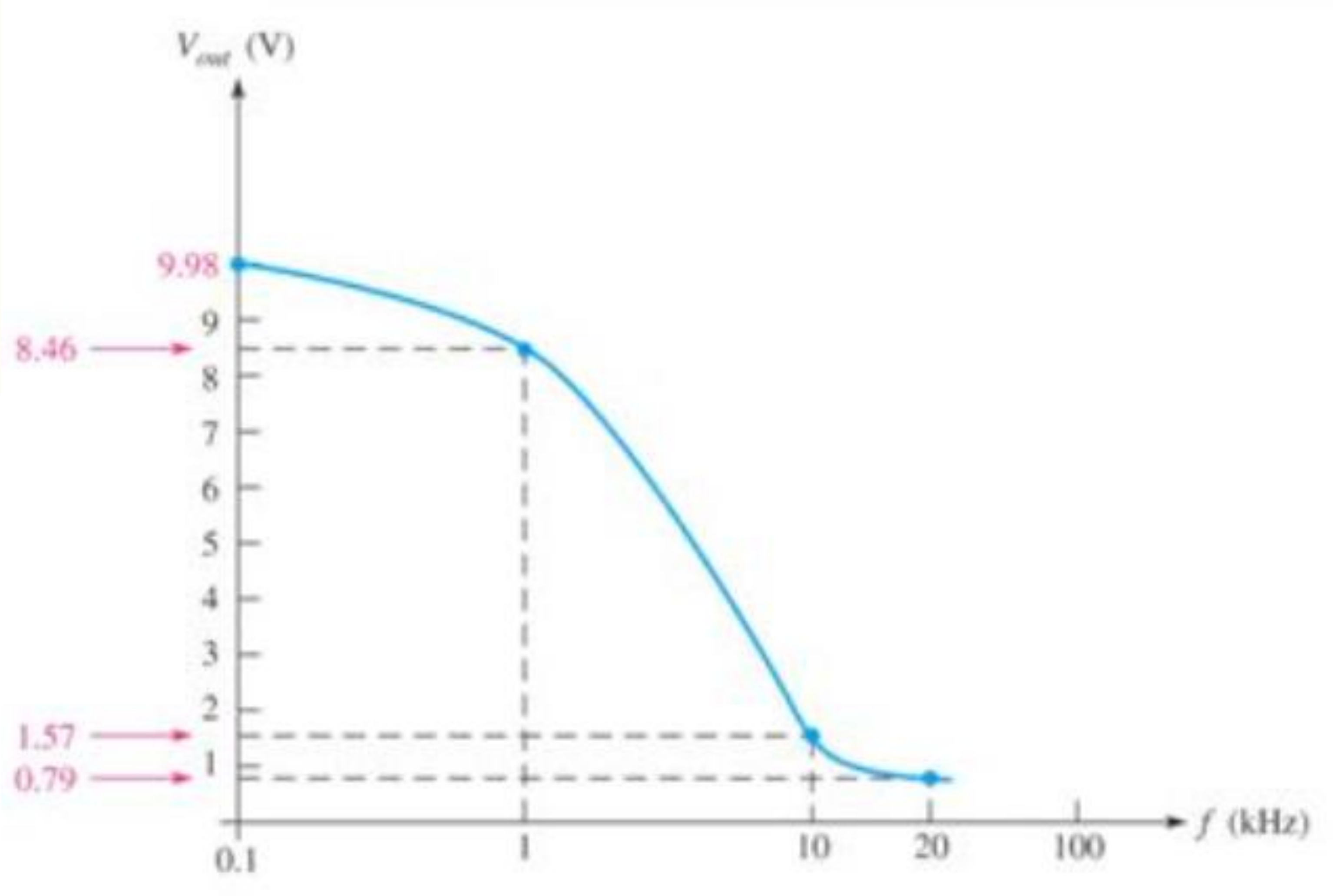


(b) $f = 1$ kHz, $X_C = 159$ Ω, $V_{out} = 8.46$ V





Passive filter



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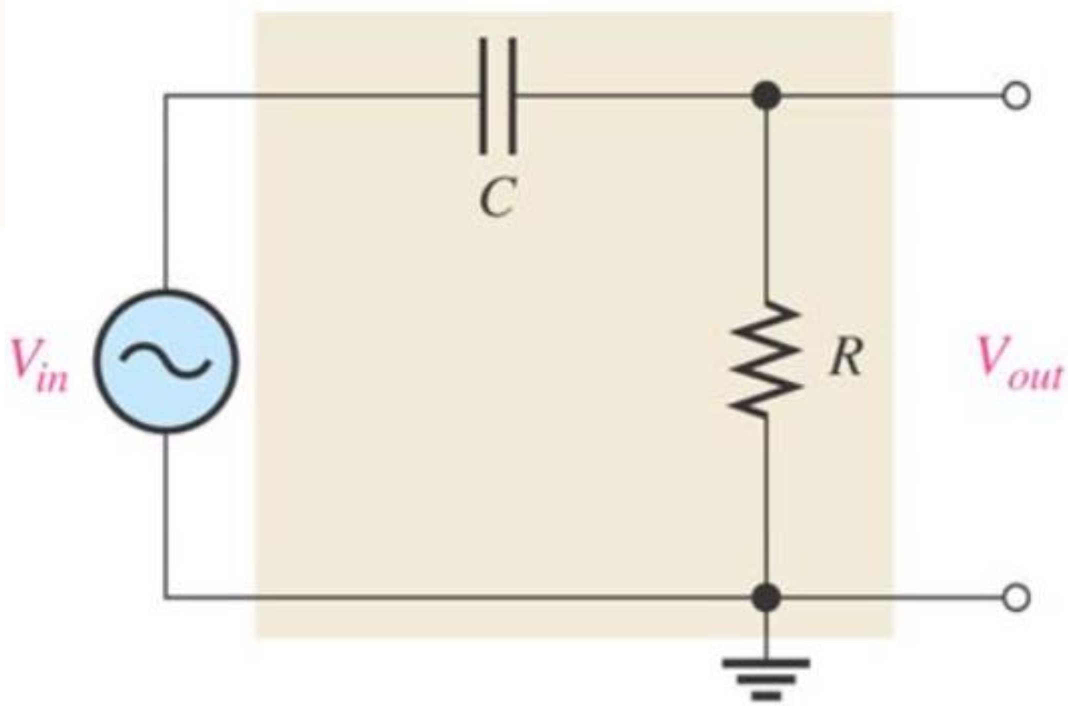
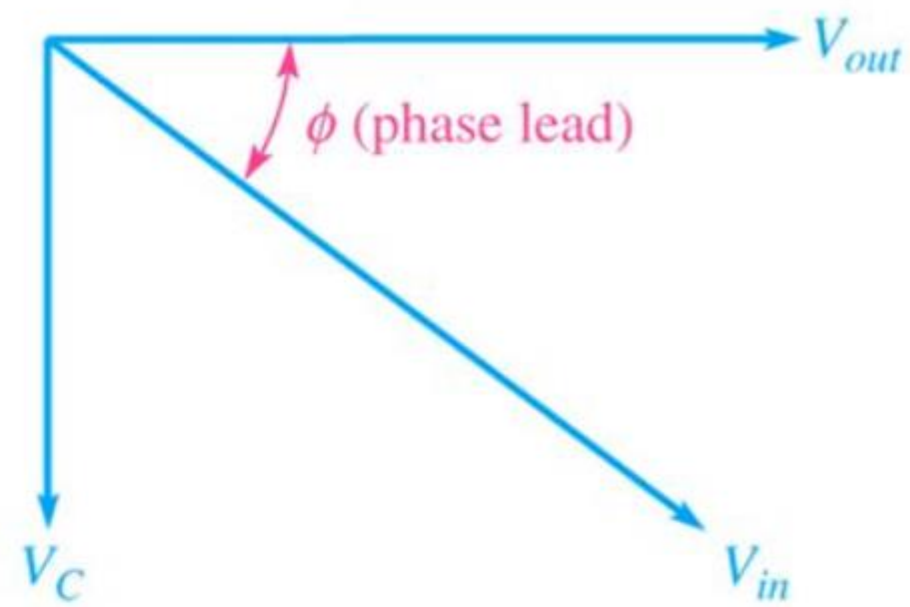
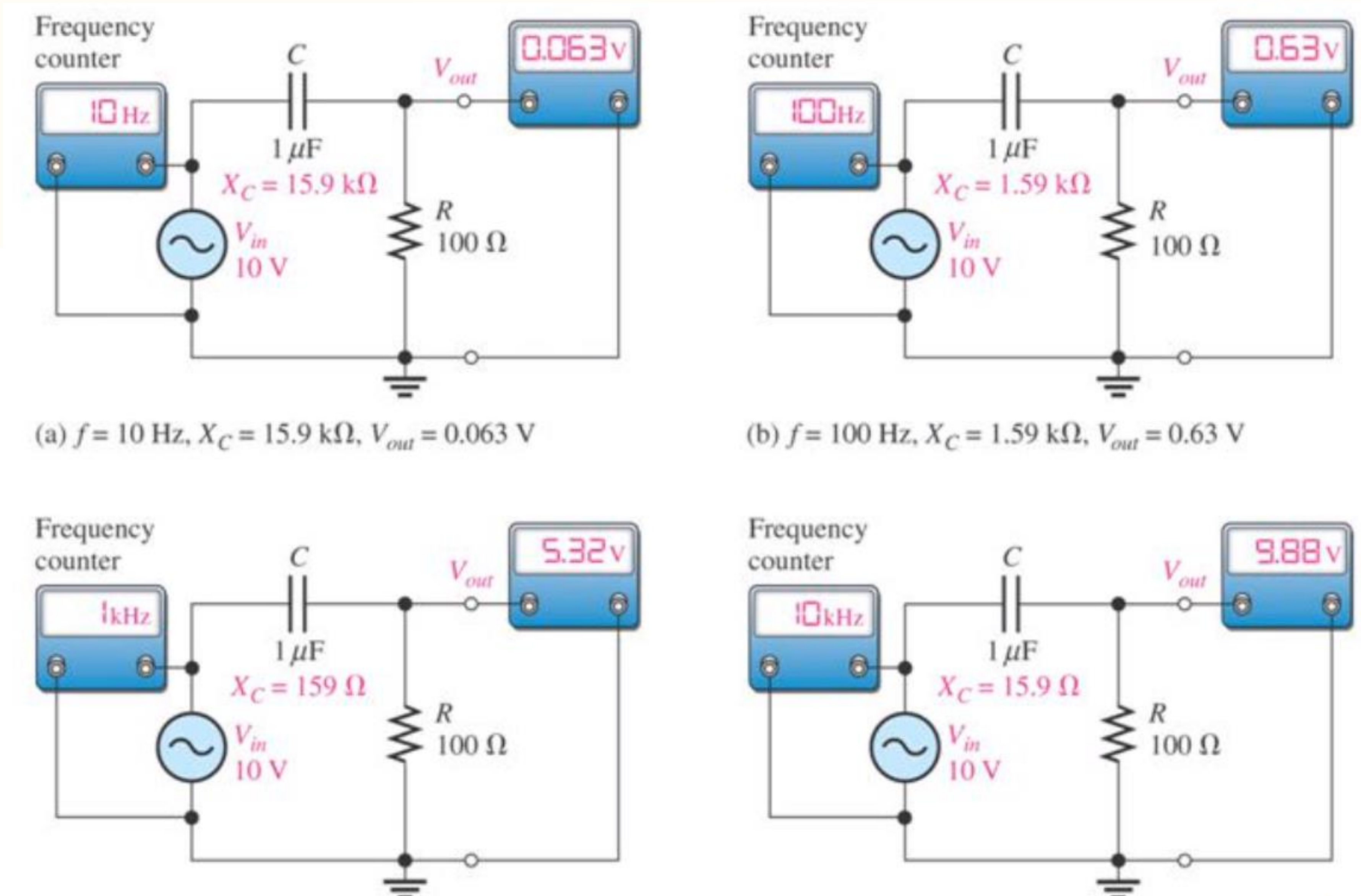
Passive filter



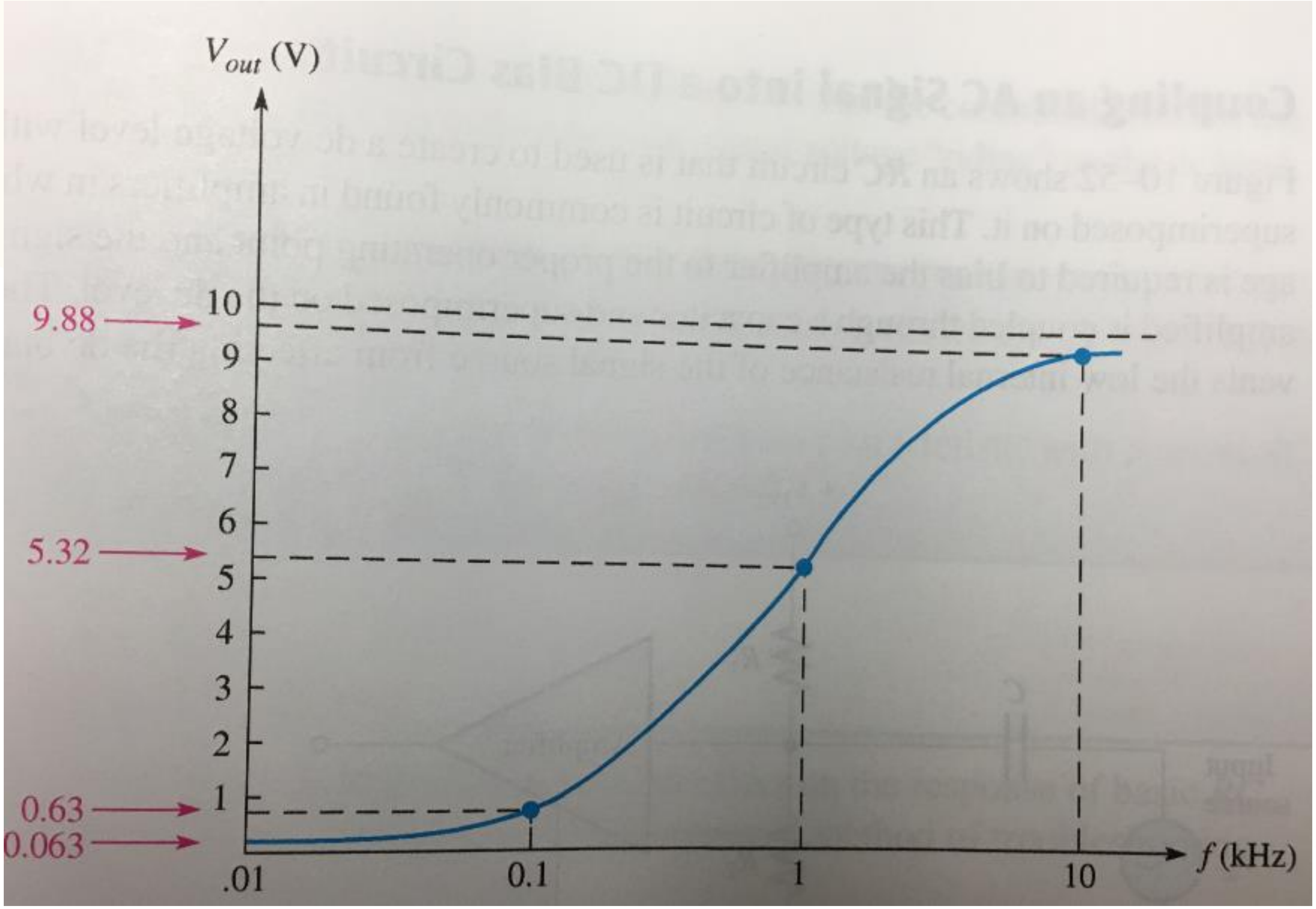


$$V_{out} = \frac{RV_{in}}{\sqrt{R^2 + X_C^2}} \qquad X_C = \frac{1}{2\pi f C}$$

Passive filter

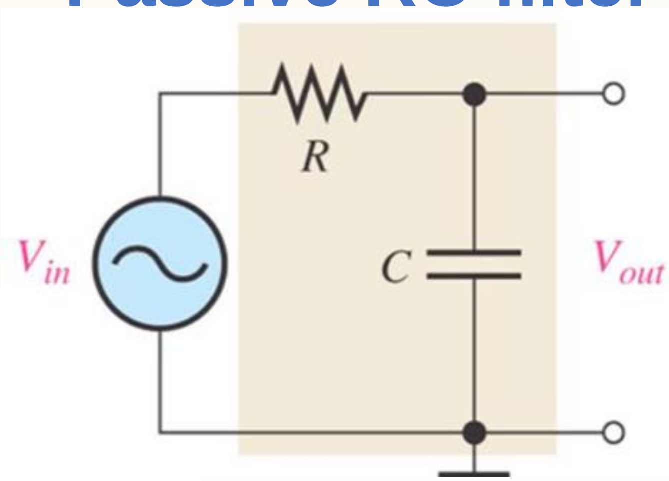


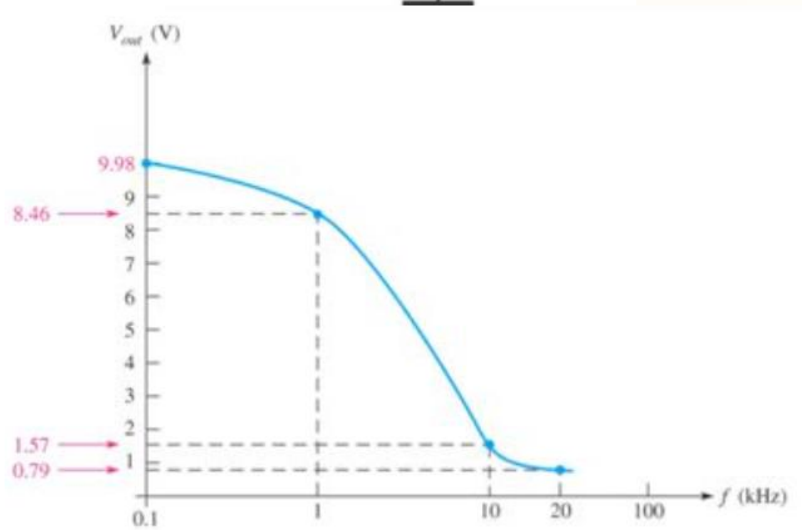
Passive filter

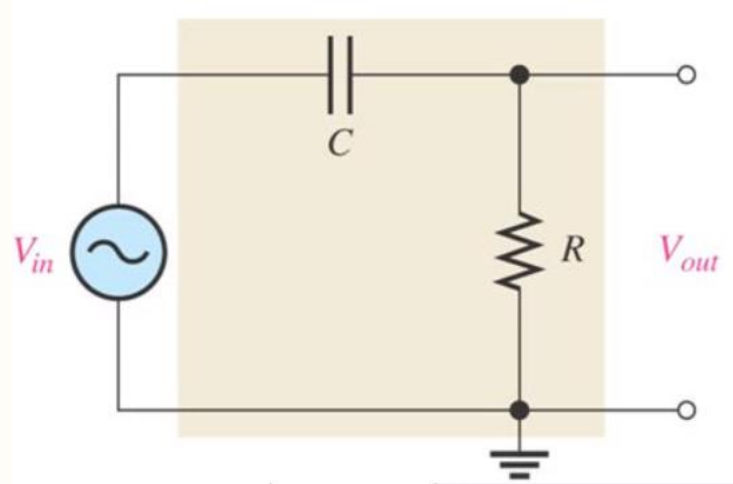


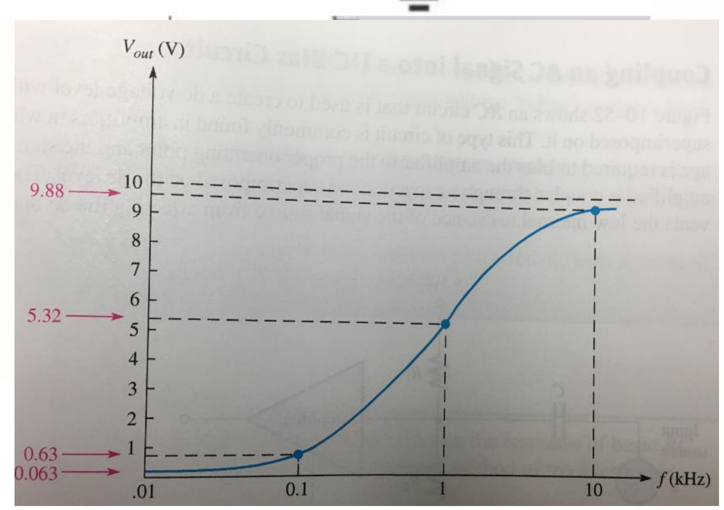
Passive filter

Passive RC filter









RC low-pass filter

RC High-pass filter

A **low-pass circuit** is realized by taking the output across the capacitor, just as in a **lag network**

A **high-pass circuit** is implemented by taking the output across the resistor, as in a **lead network**

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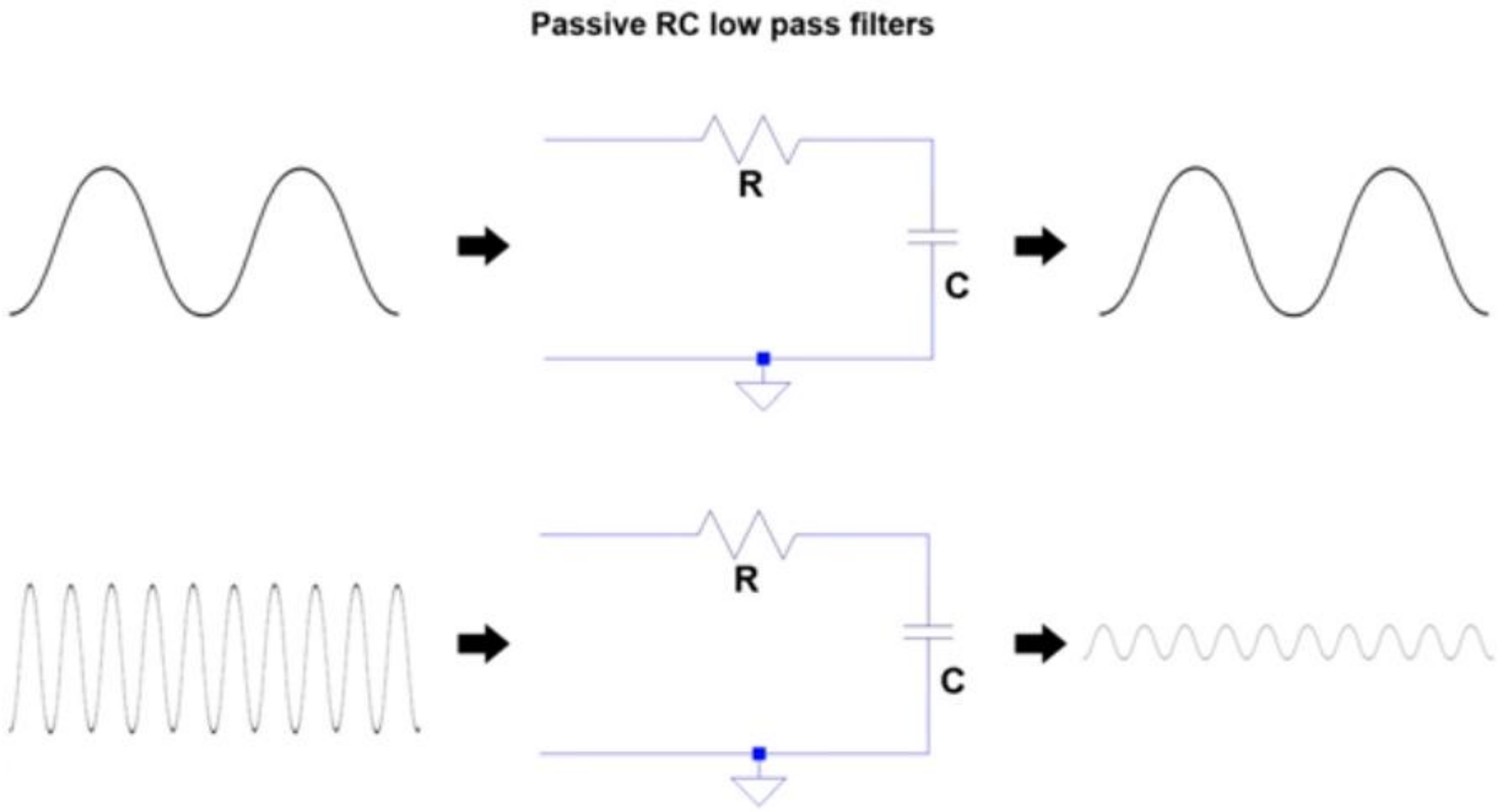
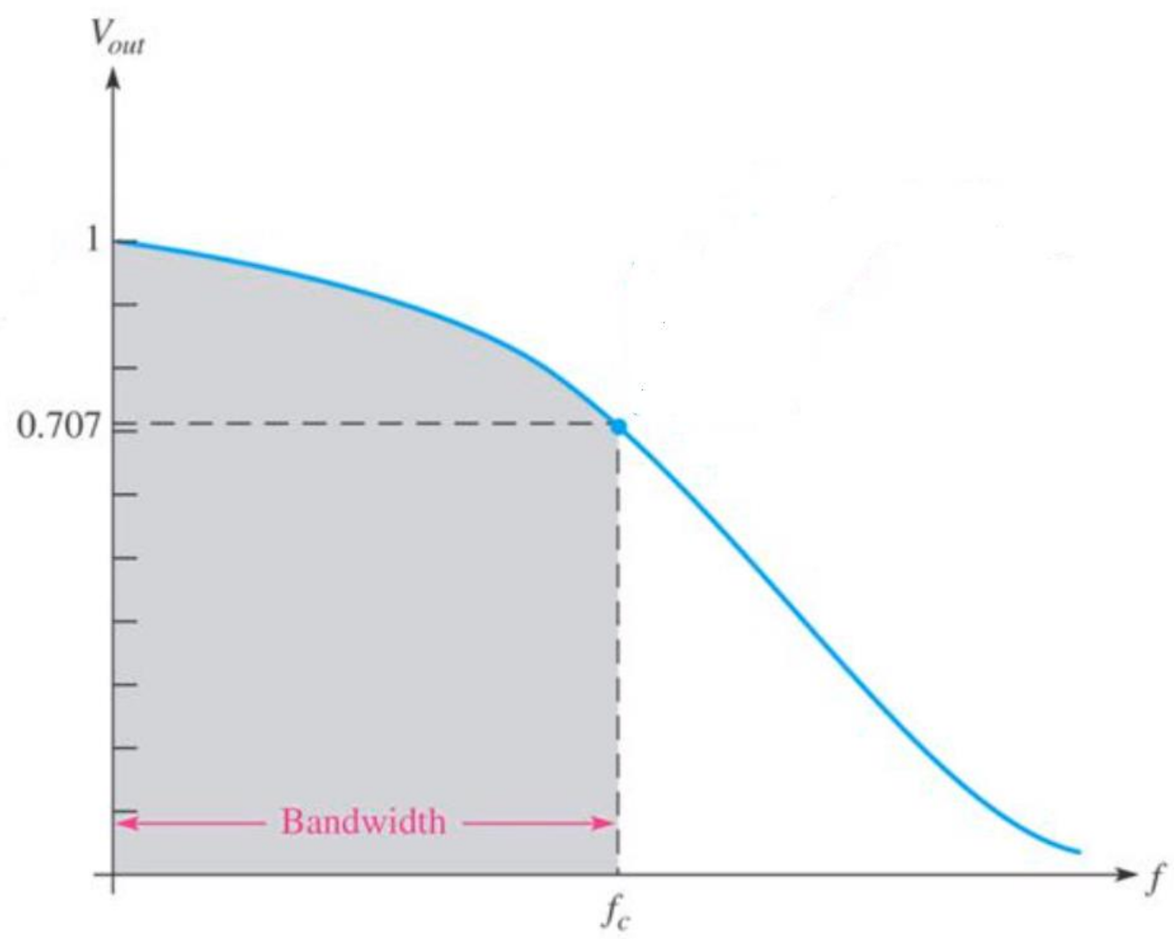
Passive filter

E. g.



Passive filter

passive RC filter



RC low-pass filter

Cut-off frequency

$$R = X_C = \frac{1}{2\pi C f_c}$$

$$f_c = \frac{1}{2\pi RC}$$

$$\theta = 45^{\circ}$$

Bandwidth

The range of frequencies that is considered to be passed from the input to the output a circuit is called a bandwidth.

Passive filter

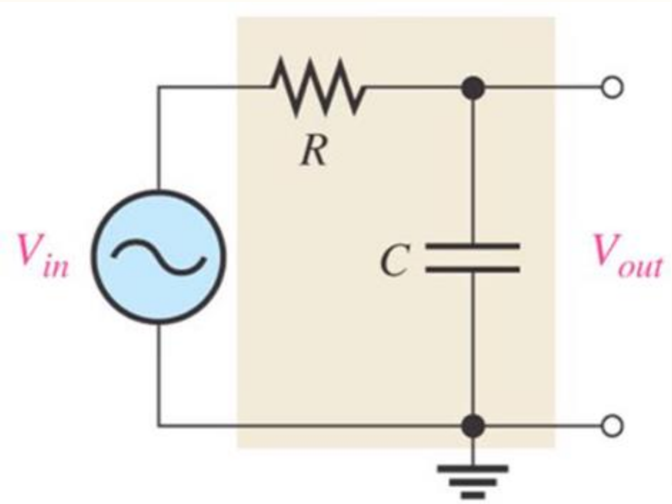
passive RC filter

Note: Cut-off frequency

$$R = X_C = \frac{1}{2\pi C f_c} \qquad f_c = \frac{1}{2\pi RC}$$

$$V_{out} = \frac{X_C V_{in}}{\sqrt{R^2 + X_C^2}}$$

E. G.



$R = 3.9k\Omega$

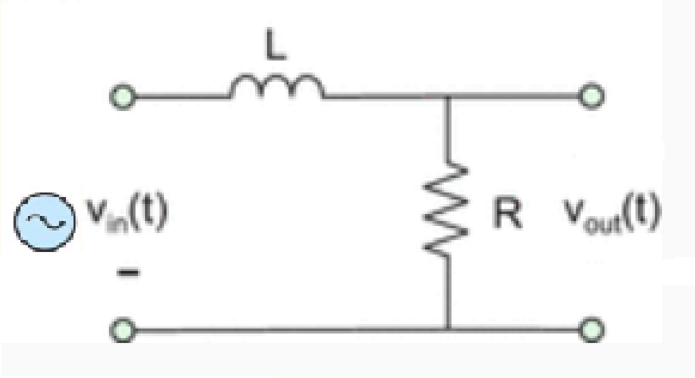
V_{in} *amplitude is* $1v$

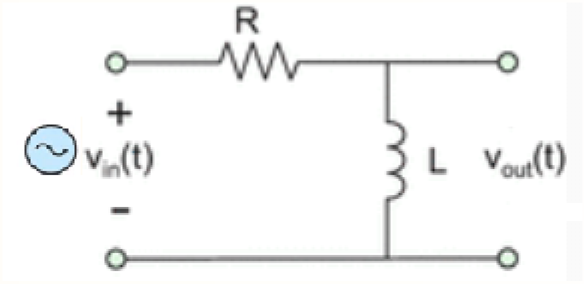
$C = 0.039\ uF$

Draw a response curve for this circuit by plotting the output voltage versus frequency for 0 Hz to 10 KHz in 1 kHz increments.

Passive filter

RL passive filter

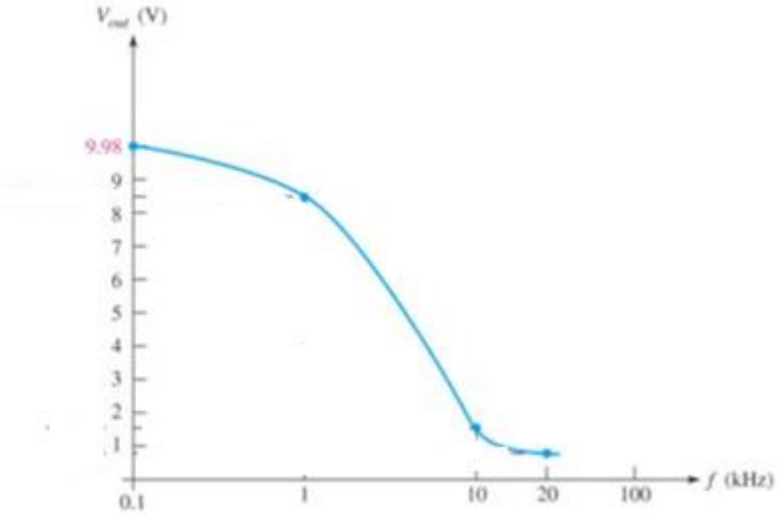


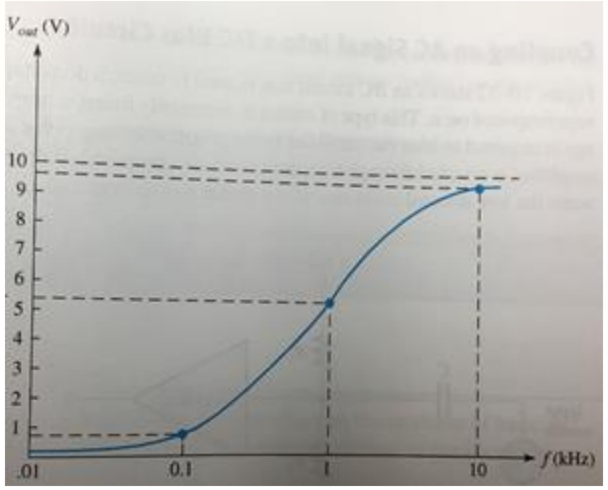


$$V_R = \frac{RV_s}{\sqrt{R^2 + X_L^2}}$$

$$X_L = 2\pi Lf$$

$$V_L = \frac{X_L V_s}{\sqrt{R^2 + X_L^2}}$$



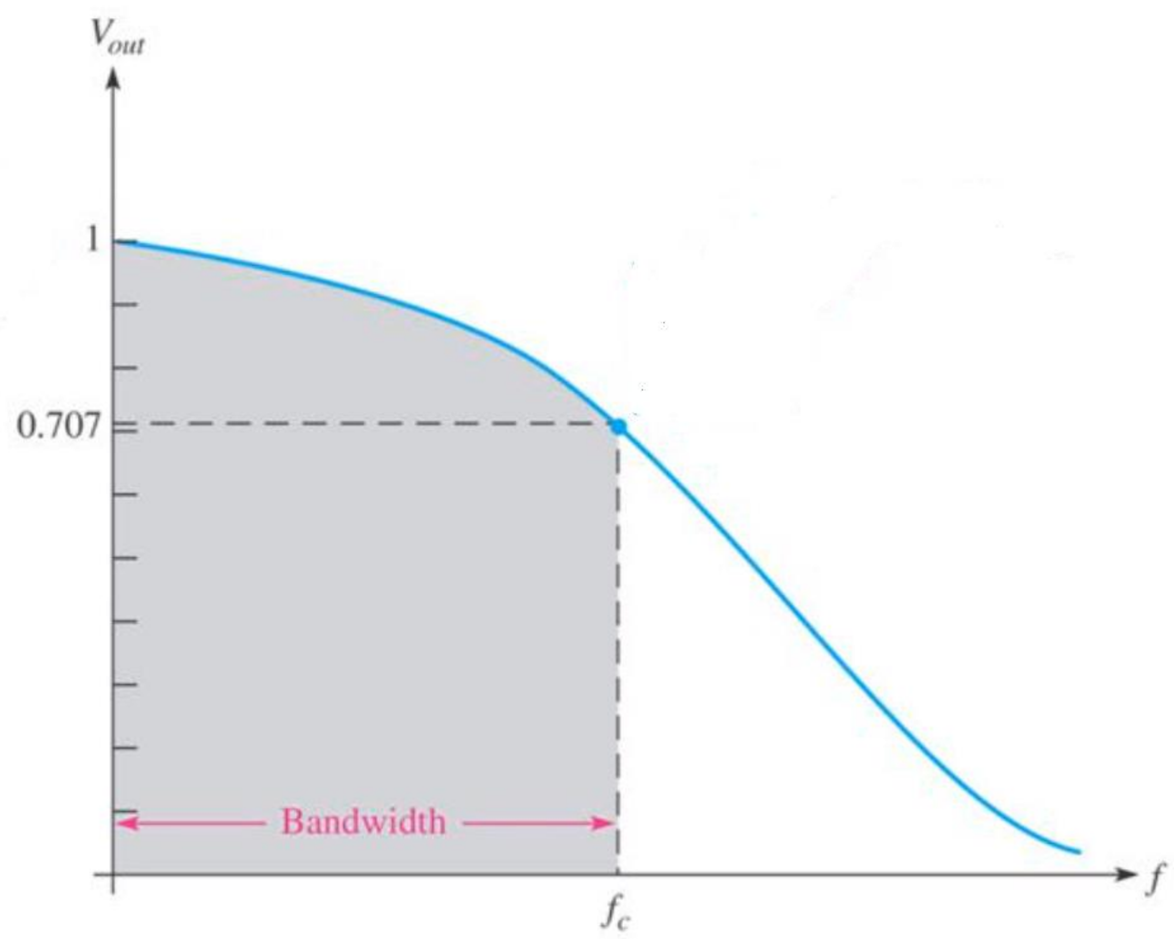


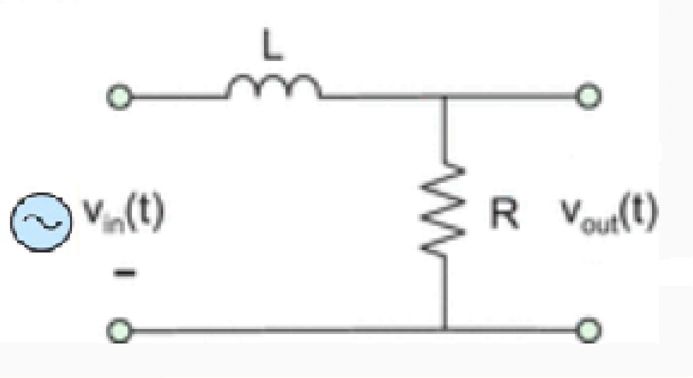
RL low-pass filter

RL High-pass filter

Passive filter

Passive RL filter





RL low-pass filter

Cut-off frequency

$$R = X_L = 2\pi L f_c$$

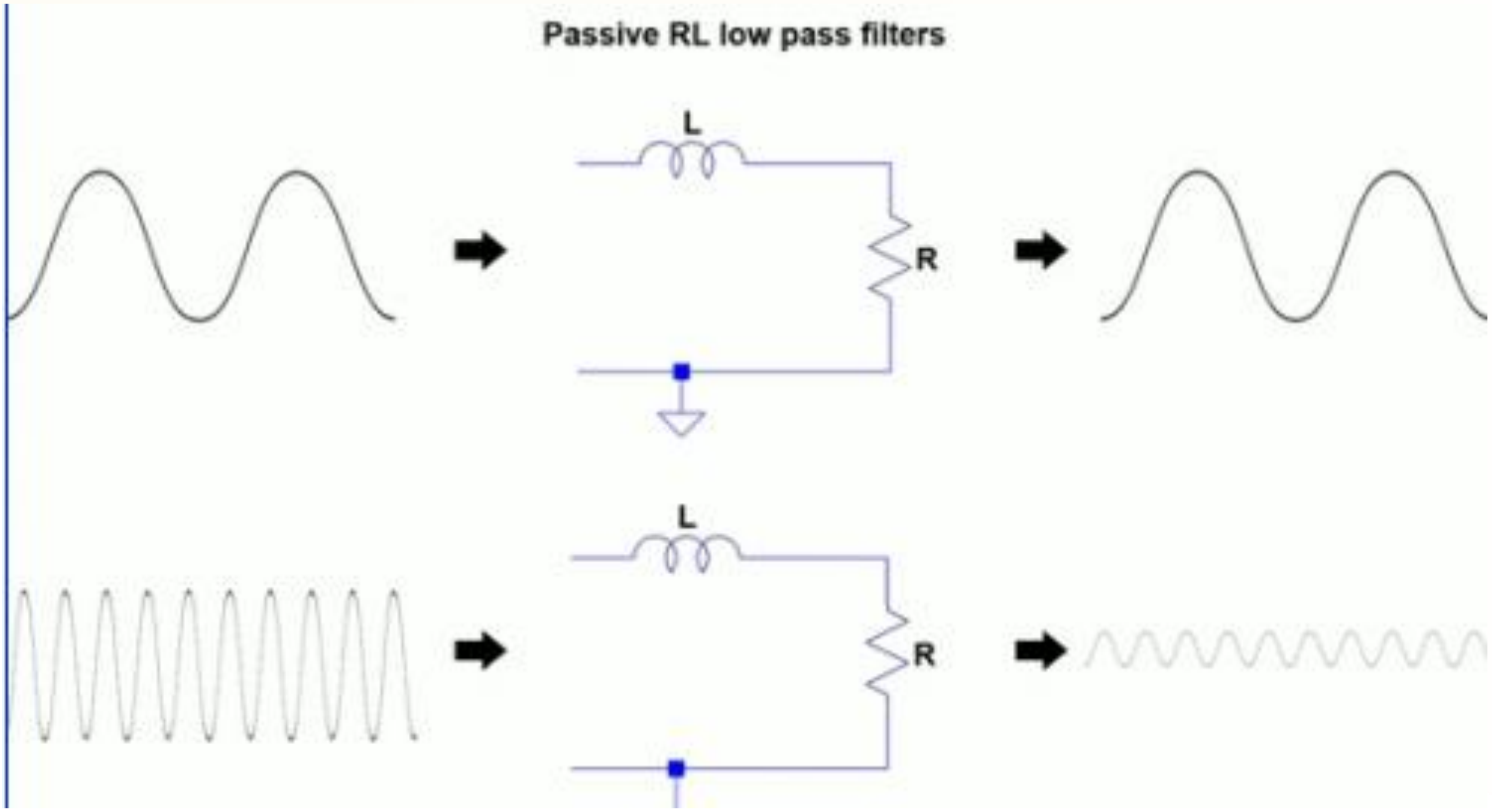
$$f_c = \frac{R}{2\pi L}$$

$$\theta = 45^{\circ}$$

Passive filter

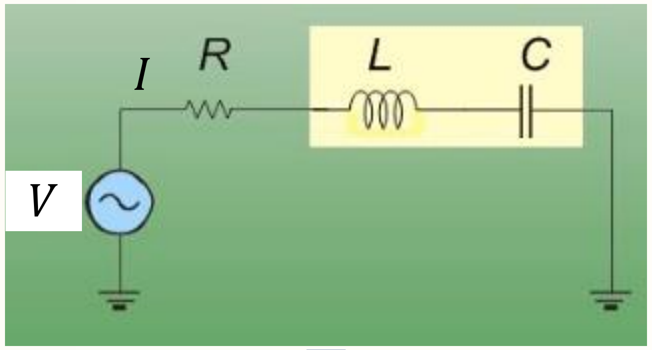
Passive RL filter

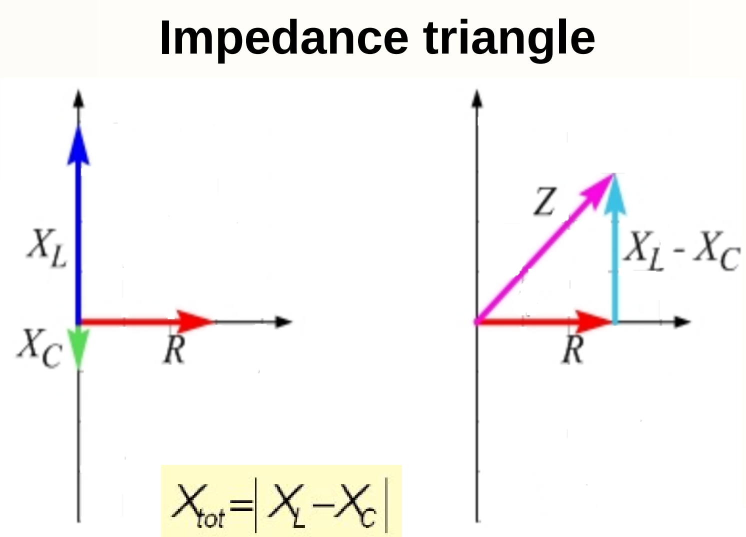
E. g.



Resonance

RCL impedance





$$X_{tot} = |X_L - X_C|$$

$$Z_{tot} = \sqrt{R^2 + X_{tot}^2}$$

$$\theta = \tan^{-1}\left(\frac{X_{tot}}{R}\right)$$

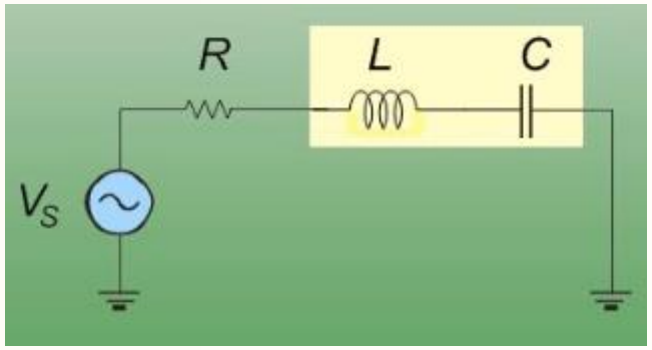
$voltage\ leads\ current\ by\ \theta\ if\ X_L > X_C$

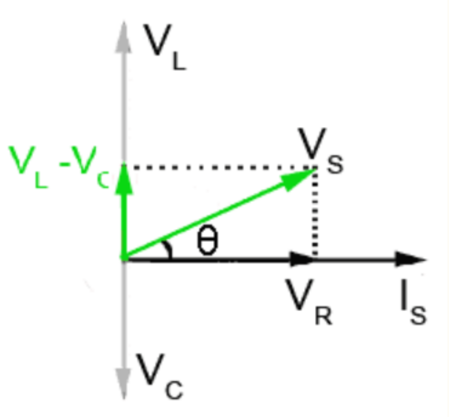
$voltage\ lags\ current\ by\ \theta\ if\ X_L < X_C$

Figures: https://slideplayer.com/slide/6379082/

Resonance

RCL voltage





$$V_R = \frac{RV_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$V_L = \frac{X_L V_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$V_C = \frac{X_C V_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$V_{LC} = \frac{|X_L - X_C| V_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$Source\ voltage\ leads\ current\ by\ \theta\ if\ X_L > X_C$

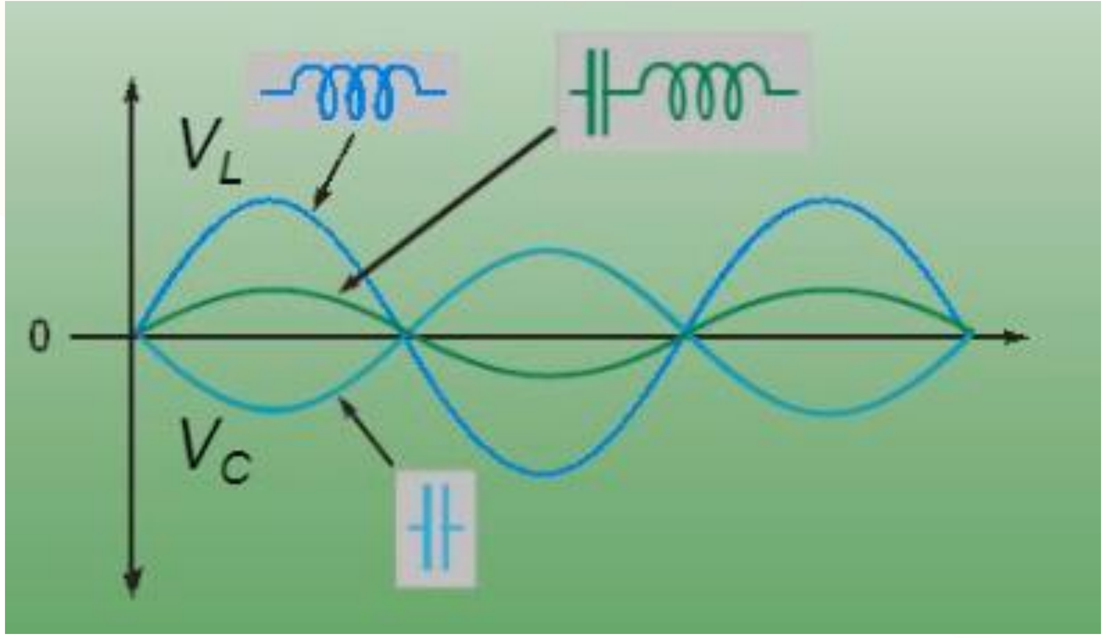
$Source\ voltage\ lags\ current\ by\ \theta\ if\ X_L < X_C$

Phase angel among I, V_R, V_L, V_C, and V_{LC}?

V_L andV_C always has 180 degree phase difference.

$E.G.$

$V_L > V_C$



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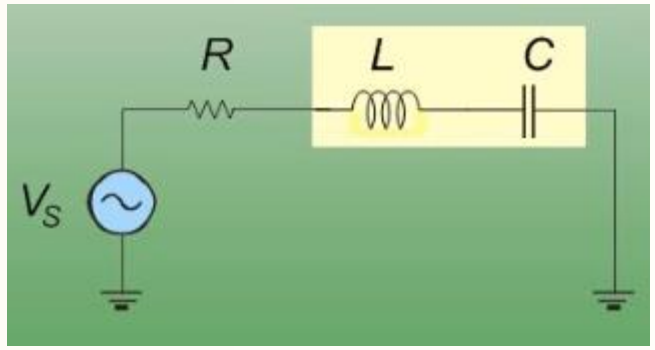
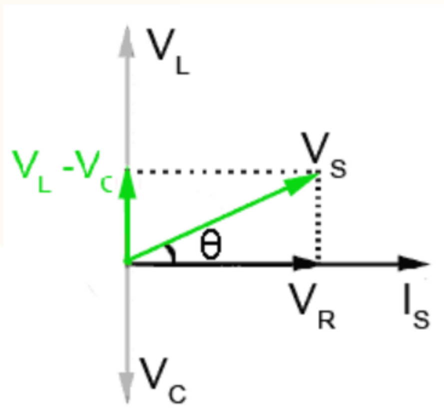




V_C and V_L always has 180 degree phase angle

$$V_R = \frac{RV_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$V_L = \frac{X_L V_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$V_C = \frac{X_C V_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$

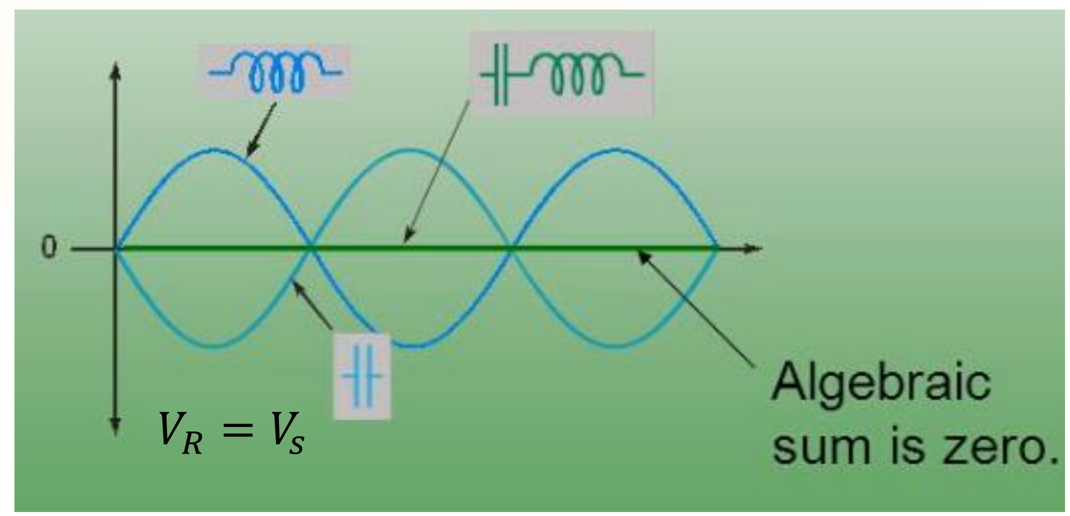
$$V_{LC} = \frac{|X_L - X_C| V_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$Source\ voltage\ leads\ current\ by\ \theta\ if\ X_L > X_C$

$Source\ voltage\ lags\ current\ by\ \theta\ if\ X_L < X_C$

Phase angel among I, V_R, V_L, V_C, and V_{LC}?

$When\ X_L = X_C?$ **Resonance**



$$V_L = V_C = \frac{X_L V_s}{R}$$

$$V_{LC} = 0$$

$Source\ voltage\ leads\ current\ by\ 0\ degree$

$Z = R$

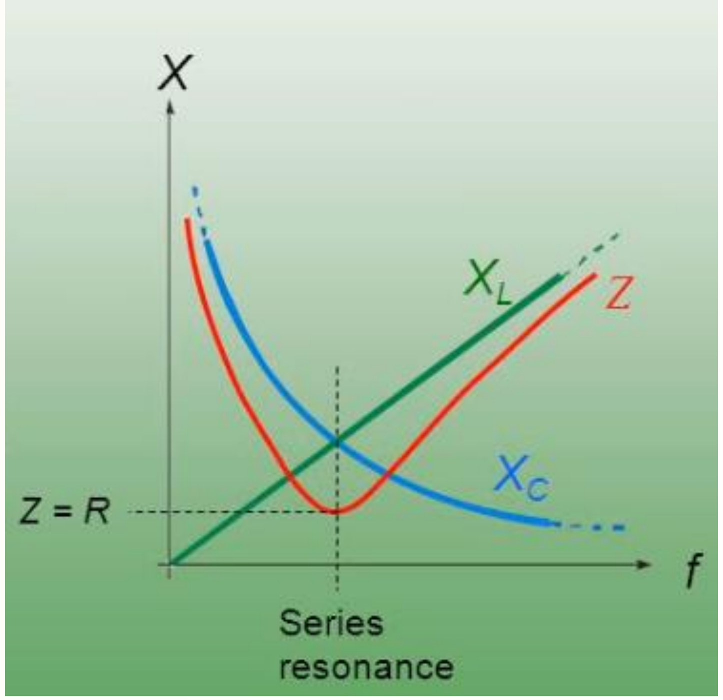
Figures: https://slideplayer.com/slide/6379082/

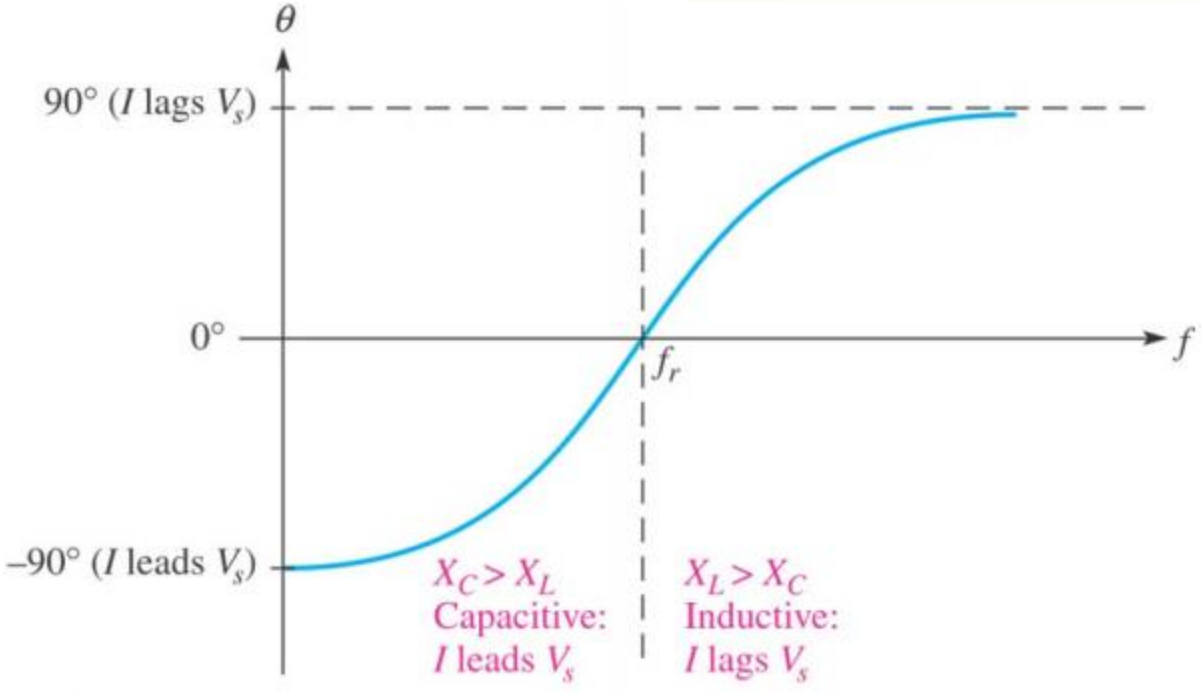
Resonance

$$when \quad X_L = X_C \qquad Resonance$$

$$2\pi L f_r = \frac{1}{2\pi C f_r}$$

$$Resonant\ frequency \qquad f_r = \frac{1}{2\pi\sqrt{LC}}$$



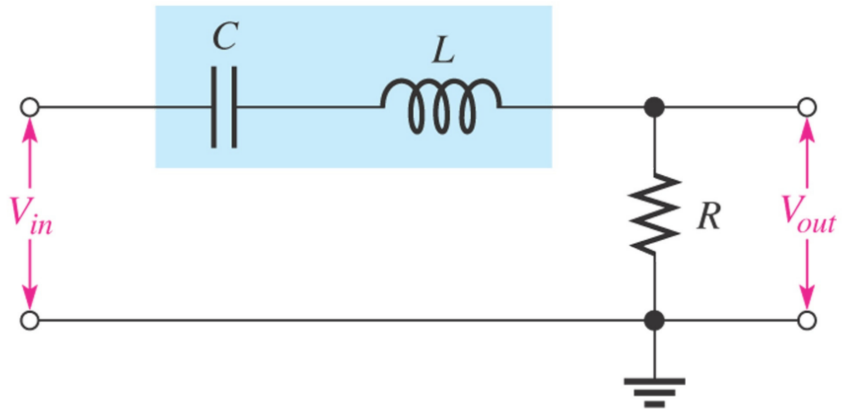


Phase angle versus frequency.

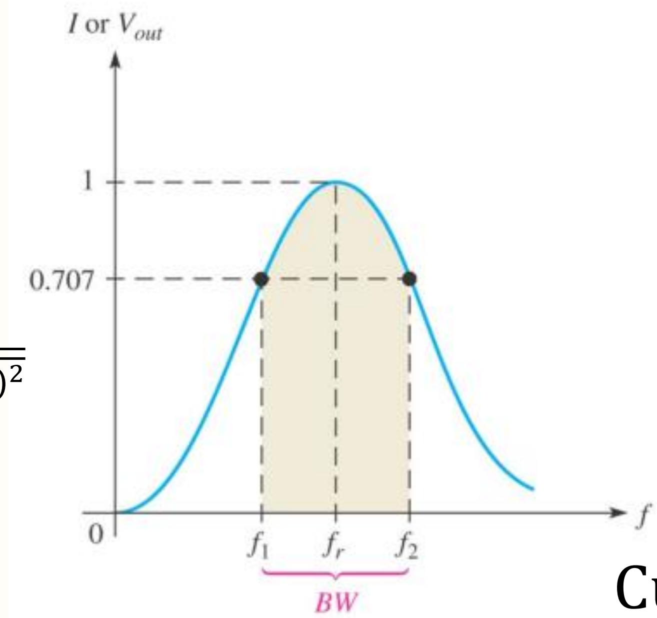
Figures: text books
https://slideplayer.com/slide/6379082/

Resonance

Resonant band-pass filter



$$V_R = \frac{RV_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$



Cutoff frequency:

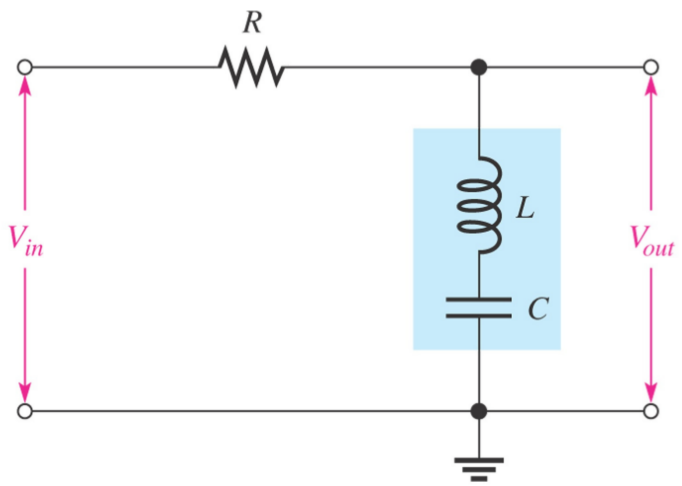
$$when\ R = |X_L - X_C|$$

f_1 is the lower cutoff frequency;

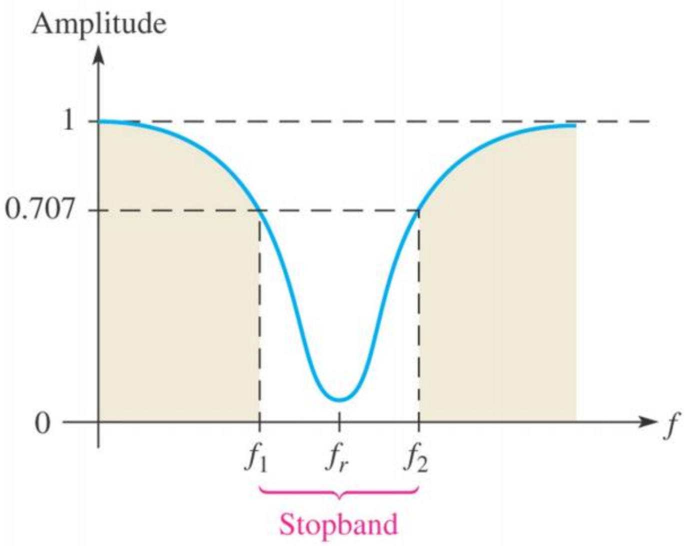
f_2 is the upper cutoff frequency.

$$Bandwidth = f_2\text{-}f_1$$

Resonant band-stop filter

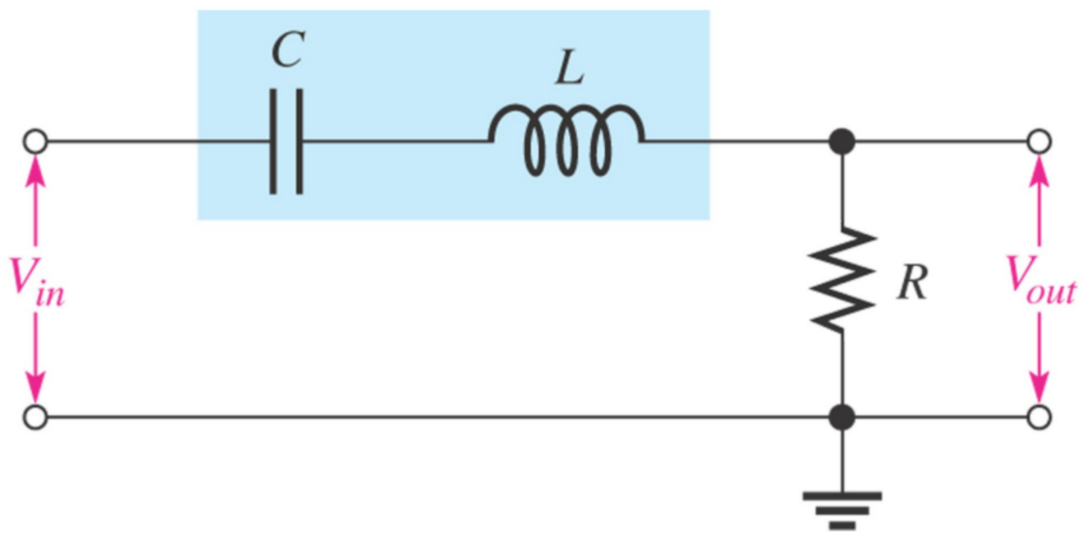


$$V_{LC} = \frac{|X_L - X_C|V_s}{\sqrt{R^2 + (X_L - X_C)^2}}$$



Resonance

Practice



Note: Cutoff frequency: $when\ R = |X_L - X_C|$ $X_C = \frac{1}{2\pi Cf}$

f_1 is the lower cutoff frequency;
f_2 is the upper cutoff frequency. $X_L = 2\pi Lf$

$Bandwidth = f_2\text{-}f_1$

$$R = 51\Omega$$

$$C = 0.0047uF$$

$$L = 10\ mH$$

$Determine\ the\ cutoff\ frequency\ and\ banthwidth.$